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(56) Documents Cited
GB 1471740 A **EP 0429094 A**

(58) Field of Search
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(54) Abstract Title
Rock bolts

(57) Rock bolts made from molybdenum and nickel free steel of the following composition percentages are % by weight): C 0.2-0.35 %; Si 0.15-0.35 %; Mn 1.10-1.40 %; P+S 0.0-0.02 %; B 0.002-0.004%; Cr 0.10-0.60 %; Al + Ti 0.02-0.05 %; the balance being iron. The bolts are subject to a heat treatment in the range 840-960 °C and then quenched in water to a temperature of 5-40 °C. A tempering treatment is not required as the steel is self tempering. Such rock bolts are from 30-300 % better at bearing loads than current A.T. rock bolts.

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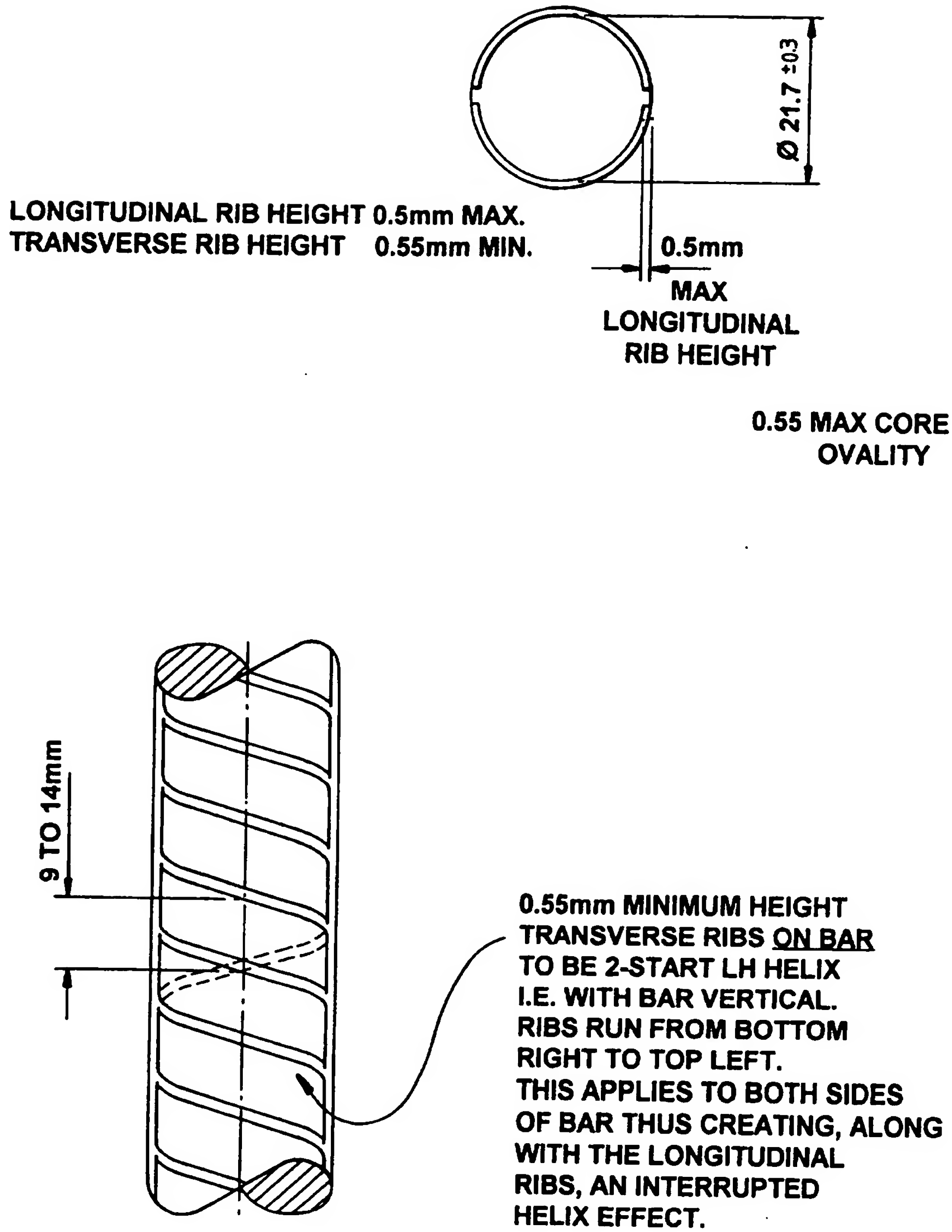

Fig. 1 **Profile of 21.7mm rockbolt**

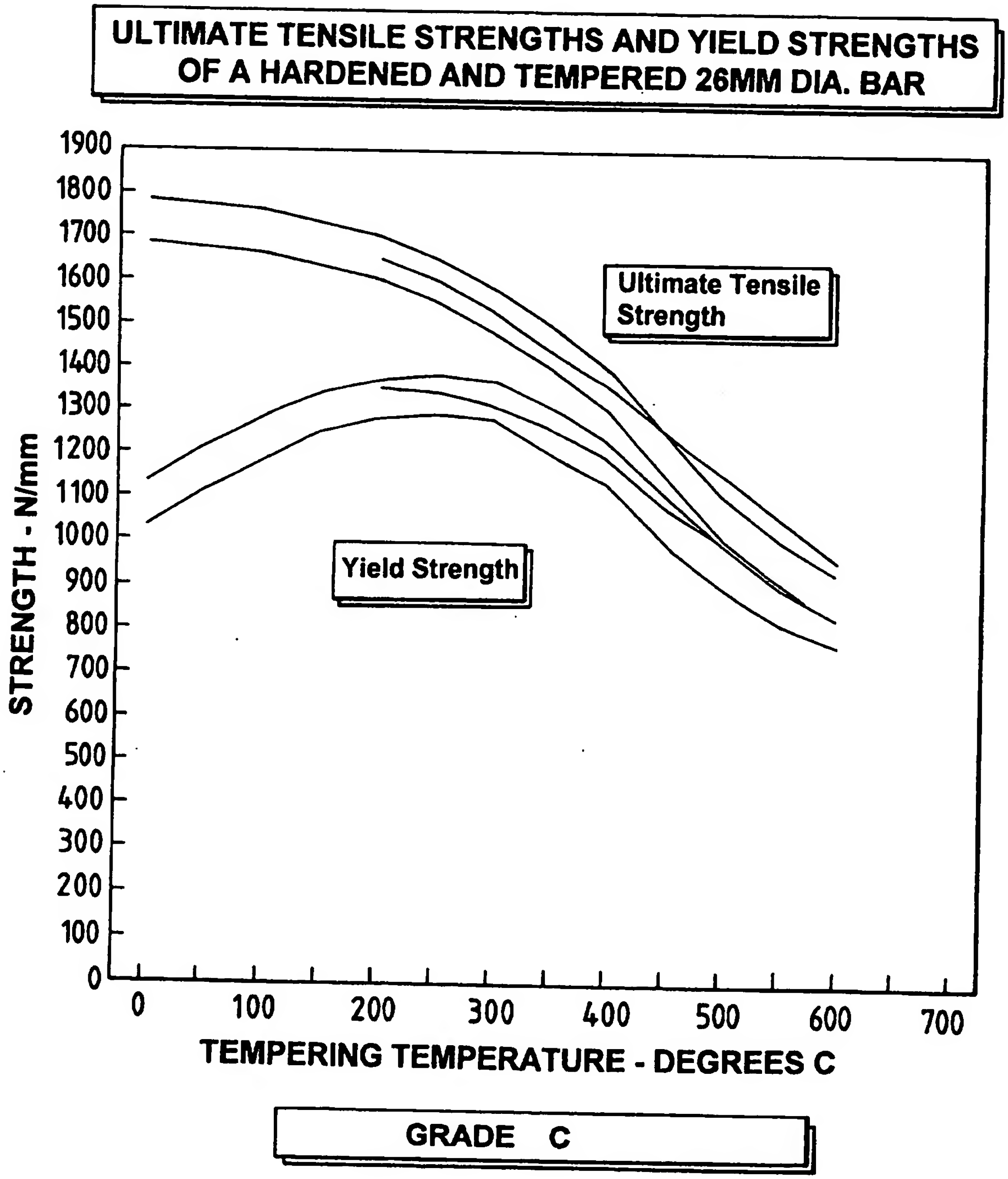
ULTIMATE TENSILE STRENGTHS AND YIELD STRENGTHS OF A HARDENED AND TEMPERED 26MM DIA. BAR
STRENGTH - N/mm
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Ultimate Tensile Strength
Yield Strength
0
100
200
300
400
500
600
700
TEMPERING TEMPERATURE - DEGREES C
GRADE C

Fig. 2

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ROCKBOLTS

This invention relates to rockbolts, more particularly as used in roofbolt systems in mines.

Over the past seven years the mining industry throughout the U.K. has adopted the slimline roofbolt system, known as the A.T. System, from Australia to reinforce rock strata. This form of rockbolt is illustrated in elevation and section in Figure 1 of the accompanying drawings.

This rockbolt system used steel having the following composition:-

Carbon (C)	0.56%
Silicon (Si)	0.21%
Manganese (Mn)	0.65%
Phosphorus (P)	0.007%
Sulphur (S)	0.009%
Aluminium (Al)	0.03%
Cobalt (Co)	0.01%
Chromium (Cr)	0.01%
Copper (Cu)	0.05%
Molybdenum (Mo)	0.01%
Niobium (Nb)	0.01%
Nickel (Ni)	0.05%
Titanium (Ti)	0.01%
Vanadium (V)	$< 0.01\%$
Tungsten (W)	0.02%
Iron (Fe)	Balance to 100%

As conditions in the U.K. mines are much more arduous than in Australian mines the rockbolts used have had to be modified to increase their load bearing tensile strength, this being

achieved by changing the basic chemistry of the rockbolt raw material, the composition of which is as follows:-

Carbon (C)	0.21%
Silicon (Si)	0.36%
Manganese (Mn)	1.23%
Phosphorus (P)	0.016%
Sulphur (S)	0.029%
Aluminium (Al)	<0.01%
Cobalt (Co)	0.01%
Chromium (Cr)	0.07%
Copper (Cu)	0.31%
Molybdenum (Mo)	0.02%
Niobium (Nb)	0.01%
Nickel (Ni)	0.10%
Titanium (Ti)	<0.01%
Vanadium (V)	0.16%
Tungsten (W)	0.03%
Iron (Fe)	Balance to 100%

This current bolt has been fully documented and is produced to a B.S.I. Standard 7861. However, this U.K. standard bolt is still not strong enough in many highly stressed rock reinforcement applications, and the mining companies are having to install more bolts per square metre of roof to be supported than comparable mines in Australia, or in most instances the rest of the world. To illustrate this point, to support a 4.0 metre wide roadway in a typical Australian mine may only require 6 bolts/metre, whereas in a U.K. mine a metre wide roadway often requires

12 bolts/metre for the equivalent level of strata control and roof support. This places several economic disadvantages on the U.K. mine operators, not just the purchase of more of the higher strength bolts, but also the actual installation costs are doubled and these installation costs are at least 6 times the cost of the actual bolt hardware.

To combat these problems the U.K. mining industry has tried to use larger diameter bolts made from the same raw material as the A.T. bolt to increase the bolt support strength and also reduce the number of bolts required for each square metre of roof to be supported. These larger bolts have not been a success for two reasons; initially the bolt weight increased significantly to affect safe handling and installation, and secondly, as the larger diameter bolt requires a larger hole drilling in the roof to be supported, installation time increased, so the perceived benefit of the larger rockbolts did not materialise.

The U.K. mining industry is therefore suffering from a combination of the current rockbolt being below rock strata load demands, and the penalty cost of installing additional rockbolts to try and compensate for the current A.T. rockbolts limited capabilities.

The object of the present invention is to overcome these problems.

According to the present invention, a rockbolt as illustrated in Figure 1 is made of chrome boron steel of the following composition:-

Carbon (C)	0.20 to 0.35%
Silicon (Si)	0.15 to 0.35%
Manganese (Mn)	1.10 to 1.40%
Phosphorous (P) + Sulphur (S)	0.02% maximum
Boron (B)	0.002 to 0.004%
Chromium (Cr)	0.10 to 0.60%
Nickel (Ni)	Nil

Molybdenum (Mo)	Nil
Aluminium (Al) + Titanium (Ti)	0.02 to 0.05%
Iron (Fe)	Balance to 100%

and subjected to heat treatment as follows:-

heated in a furnace to within the range 840°C - 960°C and maintained at that temperature for sufficient time to be heated throughout, then quenched in water at a temperature in the range 5°C - 40°C. No separate tempering is necessary as this chrome boron steel is self-tempering.

Such a rockbolt will give a better range of load bearing qualities that are from 30% to 300% better than the current A.T. rockbolt, but which at the same time retains all the dimensional, weight and manual handling advantages.

Preferred grades of chrome boron steel for the manufacture of rockbolts according to the invention are:-

	Grade A	Grade B	Grade C	Grade D
C	0.20 to 0.25	0.25 to 0.30	0.25 to 0.30	0.30 to 0.35
Si	0.15 to 0.35	0.15 to 0.35	0.15 to 0.35	0.15 to 0.35
Mn	1.10 to 1.30	1.10 to 1.40	1.10 to 1.40	1.10 to 1.40
P + S	0.02 max	0.02 max	0.02 max	0.02 max
B	0.002 to 0.004	0.002 to 0.004	0.002 to 0.004	0.002 to 0.004
Cr	0.10 to 0.20	0.10 to 0.20	0.30 to 0.50	0.40 to 0.60
Ni	Nil	Nil	Nil	Nil
Mo	Nil	Nil	Nil	Nil
Al+Ti	0.02 to 0.05	0.02 to 0.05	0.02 to 0.05	0.02 to 0.05
Fe	Balance	Balance	Balance	Balance

These materials are well proven in many industries. Boron in particular increases a steel's hardenability and toughness through heat treatment to more than double that of a traditional steel used for rockbolts. The graphs in Figure 2 of the accompanying drawings show typical strengths of chrome boron steel of Grade C generally available for converting by rolling into rockbolts in accordance with Figure 1.

There are many other practical advantages to this range of materials including the avoidance of hardening cracks, essential for rockbolt applications:-

self tempering during quenching;

reduced surface decarburization which means that any thread rolling can be carried out in the soft condition prior to heat treatment;

repeatability of the heat treatment properties is well proven and essential for this rockbolting duty.

The use of rockbolts in accordance with the present invention in lieu of the current A. T. Rockbolt affords the mining engineer the choice of either taking the additional reinforcement strength advantage at little extra cost or, more likely, to dramatically reduce installation costs by reducing the bolts per square metre intensity required to support prevailing roof and rock conditions; especially in areas where high horizontal and vertical strata loading conditions render the current A. T. specification rockbolt uneconomic.

Some of the most significant benefits, improved safety, roof control and installation costs are obvious, but one major benefit to the mine operator is that the rate at which tunnels or mine roadways are cut, can (by using fewer high strength rockbolts in lieu of the existing A. T. rockbolt) be improved by 10 to 25%. Such productivity changes are essential to ensure long term viability of many U.K. mines and also in the rest of the world.

CLAIMS

1 A rockbolt as illustrated in Figure 1 made of chrome boron steel of the following composition:-

Carbon (C)	0.20 to 0.35%
Silicon (Si)	0.15 to 0.35%
Manganese (Mn)	1.10 to 1.40%
Phosphorous (P) + Sulphur (S)	0.02% maximum
Boron (B)	0.002 to 0.004%
Chromium (Cr)	0.10 to 0.60%
Nickel (Ni)	Nil
Molybdenum (Mo)	Nil
Aluminium (Al) + Titanium (Ti)	0.02 to 0.05%
Iron (Fe)	Balance to 100%

and subjected to heat treatment as follows:-

heated in a furnace to within the range 840°C - 960°C and maintained at that temperature for sufficient time to be heated throughout. then quenched in water at a temperature in the range 5°C - 40°C.

2. A rockbolt as in Claim 1 having the following composition:-

C	0.20 to 0.25
Si	0.15 to 0.35
Mn	1.10 to 1.30
P + S	0.02 max
B	0.002 to 0.004
Cr	0.10 to 0.20

Ni	Nil
Mo	Nil
Al+Ti	0.02 to 0.05
Fe	Balance

3. A rockbolt as in Claim 1 having the following composition:-

C	0.25 to 0.30
Si	0.15 to 0.35
Mn	1.10 to 1.40
P + S	0.02 max
B	0.002 to 0.004
Cr	0.10 to 0.20
Ni	Nil
Mo	Nil
Al+Ti	0.02 to 0.05
Fe	Balance

4. A rockbolt as in Claim 1 having the following composition:-

C	0.25 to 0.30
Si	0.15 to 0.35
Mn	1.10 to 1.40
P + S	0.02 max
B	0.002 to 0.004
Cr	0.30 to 0.50
Ni	Nil
Mo	Nil

Al+Ti	0.02 to 0.05
Fe	Balance

5. A rockbolt as in Claim 1 having the following composition:-

C	0.30 to 0.35
Si	0.15 to 0.35
Mn	1.10 to 1.40
P + S	0.02 max
B	0.002 to 0.004
Cr	0.40 to 0.60
Ni	Nil
Mo	Nil
Al+Ti	0.02 to 0.05
Fe	Balance

The Patent Office

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Claims searched: 1-5

Examiner: Matthew Lawson
Date of search: 7 April 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): C7A

Int Cl (Ed.6): E21D 21/00

Other: -

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 1471740 A (HOOGOVENS)	
A	EP 0429094 A1 (KOBE STEEL)	

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
Y Document indicating lack of inventive step if combined with one or more other documents of same category.	P Document published on or after the declared priority date but before the filing date of this invention.
& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.